CLAIMS

1. Apparatus for steering a directional audio beam that is self-demodulated from an ultrasound carrier, said apparatus including:

means for generating an audio signal;

means for generating an ultrasound carrier signal;

means for modulating said carrier signal with said audio signal;

means for adjusting the amplitude and phase of at least one of said audio signal and said carrier signal to steer said audio beam to a desired direction; and

means for generating an ultrasound beam in said direction driven by said modulated carrier signal.

2. Apparatus according to claim 1 including means for suppressing a sidelobe of the ultrasound beam.

3. Apparatus according to claim 1 including means for weighting said audio and/or carrier signal by a zeroth order Bessel function to synthesize a Bessel distribution source.

4. Apparatus according to claim 3 wherein said means for generating an ultrasound beam includes a plurality of ultrasound transducer elements and said means for weighting includes a plurality of adjustable gain and delay elements, each gain and delay element corresponding to a respective transducer element.

5. Apparatus according to claim 1, 2 or 3 wherein said means for generating an ultrasound beam includes a plurality of ultrasound transducer elements and a corresponding plurality of matching filters adapted to adjust the phase of the modulated carrier signal to the resonant frequency of the associated transducer element.

6. Apparatus according to any one of the preceding claims wherein said means for generating an audio signal includes at least one of a CD player, FM radio receiver and digital broadcast radio receiver.

7. Apparatus according to any one of the preceding claims including means for preprocessing said audio signal to reduce distortion of said self-demodulated audio beam.

8. Apparatus according to any one of the preceding claims wherein said means for generating an ultrasound beam includes a plurality of ultrasound transducer elements arranged in an annular or substantially annular array.

9. Apparatus for steering a directional audio beam that is self-demodulated from an ultrasound carrier, said apparatus including:

means for generating an audio signal;

means for generating an ultrasound carrier signal;

means for modulating said carrier signal with said audio signal;

means for generating an ultrasound beam driven by said modulated carrier signal; and

means for adjusting said means for generating to steer said audio beam to a desired location.

10. Apparatus according to claim 9 wherein said means for generating includes a plurality of transducer elements and said means for adjusting includes a stepper motor for rotating said transducer elements relative to at least one axis.

11. Apparatus according to claim 9 or 10 including a video camera for providing an image of a potential listener, means for detecting the location of the listener from said image and means to control said means for adjusting to steer said means for generating towards said location.

12. Apparatus according to any one of the preceding claims wherein said audio beam is reflected from an intermediate surface such as a billboard panel.

13. A method of steering a directional audio beam that is self-demodulated from an ultrasound carrier, said method including the steps of:

generating an audio signal;

generating an ultrasound carrier signal;

modulating said carrier signal with said audio signal;

adjusting the amplitude and phase of at least one of said audio signal and said carrier signal to steer said audio beam to a desired direction; and

generating an ultrasound beam in said direction driven by said modulated carrier signal.

14. Method according to claim 13 including suppressing a sidelobe of the ultrasound beam.

15. Method according to claim 13 including weighting said audio and/or carrier signal by a zeroth order Bessel function to synthesize a Bessel distribution source.

16. Method according to claim 14 wherein said step of generating an ultrasound beam includes driving a plurality of ultrasound transducer elements with said modulated carrier signal and said step of weighting includes adjusting gain and delay of said audio and/or carrier signal prior to driving each transducer element.

17. Method according to claim 13, 14 or 15 wherein said step of generating an ultrasound beam includes driving a plurality of ultrasound transducer elements via a corresponding plurality of matching filters adapted to adjust the phase of the modulated carrier signal to the resonant frequency of the associated transducer element.

18. Method according to any one of claims 13 to 17 wherein said step of generating an audio signal is performed by means of at least one of a CD player, FM radio receiver and digital broadcast radio receiver.

19. Method according to any one of claim 13 to 18 including preprocessing said audio signal to reduce distortion of said self-demodulated audio beam.

20. Method according to any one of claims 13 to 19 wherein said step of generating an ultrasound beam is performed by means of a plurality of ultrasound transducer elements arranged in an annular of substantially annular array.

21. Method for steering a directional audio beam that is self-demodulated from an ultrasound carrier, said method including the steps of:

generating an audio signal;

generating an ultrasound carrier signal;

modulating said carrier signal with said audio signal;

generating an ultrasound beam driven by said modulated carrier signal; and

adjusting said means for generating to steer said audio beam to a desired direction.

22. Method according to claim 21 wherein said step of generating is performed by means of a plurality of transducer elements and said step of adjusting is performed by means of a stepper motor for rotating said transducer elements relative to at least one axis.

23. Method according to claim 21 or 22 including detecting the location of a potential listener and adjusting said means for generating to steer said audio beam towards said location.

24. Method according to any one of claims 13 to 23 including reflecting said audio beam from an intermediate surface such as a billboard panel.

25. A method of processing an audio signal, including:

performing a square root operation on the audio signal to generate a square rooted signal;

alternating the gain of the square rooted signal between positive and negative gain values at selected locations to generate a flipped signal; and

modulating the flipped signal onto a first ultrasonic carrier wave.

26. The method of claim 25 further including the step of:

offsetting the audio signal by a predetermined amount prior to performing the square root operation to ensure that the square root operation only results in real values.

27. The method of claim 26 further including the step of:

dividing the audio signal into a plurality of frames;

determining, after the offsetting step; a minimum value of a portion of the audio signal in a particular frame; and

subtracting the minimum value from the portion of the audio signal in the particular frame.

28. The method of claim 27 further including the step of:

compensating the flipped signal in adjacent frames for discontinuities resulting from subtracting different minimum amounts in adjacent frames.

29. The method of any one of claims 25 to 27 wherein the selected locations of the signal are minimum turning points of the signal.

30. The method of any one of claims 25 to 29 further including the steps of:

determining a first modulation envelope for the flipped signal;

determining a second modulation envelope for the square rooted signal;

determining the difference between the first and second modulation envelopes;

modulating the difference between the first and second modulation envelopes onto a second ultrasonic carrier wave.

31. The method of claim 30 wherein the first and second ultrasonic carrier waves are orthogonal to one another.

32. An apparatus for processing an audio signal received from an audio source, including:

a square root module to perform a square root operation on the audio signal to generate a square rooted signal;

a determining module coupled to the square root module to alternate the gain of the square rooted signal between positive and negative gain values at selected locations, thereby to generate a flipped signal; and

a modulator to modulate the flipped signal onto a first ultrasonic carrier wave.

33. The apparatus of claim 32 further including:

an offset module to offset the audio signal by a predetermined amount prior to passing the signal to the square root module.

34. The system of claim 33 further comprising:

a buffer to divide the audio signal into a plurality of frames;

a subtracting module to subtract a minimum value from the portion of the audio signal in the particular frame.

35. The system of any one of claims 32 to 34 wherein:

the determining module

determines a first modulation envelope for the flipped signal;

determines a second modulation envelope for the square rooted signal;

determines the difference between the first and second modulation envelopes;

the modulator;

modulates the difference between the first and second modulation envelopes onto a second ultrasonic carrier wave.

36. The apparatus of any one of claims 32 to 35 wherein the selected locations of the signal are minimum turning points of the signal.

37. The apparatus of claim 35 or 36 wherein the first and second ultrasonic carrier waves are orthogonal to one another.

38. The apparatus of claim 36 or 37 wherein the turning points are below a selected minimum value.

39. A method for processing an audio signal received from an audio source, including:

processing the audio signal into a first processed audio signal; processing the audio signal into a second processed audio signal;

modulating the first processed audio signal onto a first ultrasonic carrier wave; and

modulating the second processed audio signal onto a second ultrasonic carrier wave;

wherein the first and second ultrasonic carrier waves have different phases.

40. The method of claim 39 wherein the first ultrasonic carrier wave is orthogonal to the second ultrasonic carrier wave.

41. The method of claim 40 wherein the step of processing the audio signal into the first processed audio signal comprises the step of:

applying a modified square root preprocessing method to the signal.

42. The method of claim 41 wherein the step of processing the audio signal into the second processed audio signal comprises the step of:

determining the difference between the envelope of an ideal square root signal and the envelope of the first processed audio signal.

43. The method of claim 42 wherein the modified square root preprocessing method comprises the steps of:

performing a square root operation on the audio signal to generate a square rooted signal;

alternating the gain of the square rooted signal between positive and negative gain values at selected locations to generate a flipped signal.

44. The method of claim 43 wherein the modified square root method comprises the further step of:

offsetting the audio signal by a predetermined amount prior to performing the square root operation to ensure that the square root operation only results in real values.

45. The method of claim 44 wherein the selected locations of the signal are lower turning points of the signal.

46. An apparatus for processing an audio signal received from an audio source, including:

a processor to process the audio signal into a first processed audio signal and a second processed audio signal;

a modulator to modulate the first processed audio signal onto a first ultrasonic carrier wave and to modulate the second processed audio signal onto a second ultrasonic carrier wave;

wherein the first and second ultrasonic carrier waves have different phases.

47. The apparatus of claim 46 wherein the first ultrasonic carrier wave is orthogonal to the second ultrasonic carrier wave.

48. The apparatus of claim 47 wherein the processor, when processing the audio signal into the first processed audio signal, applies a modified square root preprocessing method.

49. The apparatus of claim 48 wherein the processor, when processing the audio signal into the second processed audio signal, determines the difference between the envelope of an ideal square root signal and the envelope of the first processed audio signal.

50. The apparatus of claim 49 wherein the modified square root preprocessing method applied by the processor includes the steps of:

performing a square root operation on the audio signal to generate a square rooted signal;

alternating the gain of the square rooted signal between positive and negative gain values at selected locations to generate a flipped signal.

51. The apparatus of claim 49 wherein the modified square root method preprocessing method applied by the processor includes the further step of:

offsetting the audio signal by a predetermined amount prior to performing the square root operation to ensure that the square root operation only results in real values.

52. The apparatus of claim 50 or 51 wherein the selected locations of the signal are lower turning points of the signal.

53. A method of processing an audio signal, including:

separating a low frequency component from the audio signal;

generating harmonics of the low frequency component to create a preprocessed signal; and

modulating the preprocessed signal onto an ultrasonic carrier wave.

54. The method of claim 53 further including the step of:

combining the low frequency component with the preprocessed signal prior to the modulating step.

55. The method of claim 54 further including the step of:

combining other frequency components of the audio signal with the preprocessed signal prior the modulating step.

56. The method of claim 55 further including the step of:

processing the other frequency components of the audio signal using a psycho acoustic model prior to combining the other frequency components of the audio signal with the preprocessed signal.

57. The method of claim 54 further including the steps of:

transmitting the preprocessed signal from a first ultrasonic emitter after the modulation step.

58. The method of claim 57 further including the step of:

modulating other frequency components of the audio signal onto an ultrasonic carrier wave; and

transmitting the modulated other frequency components of the audio

signal using the first ultrasonic transmitter or a second ultrasonic emitter.

59. The method of claim 58 wherein the preprocessed signal is modulated using an ultrasonic carrier wave having a first frequency and the other frequency components are modulated using an ultrasonic carrier wave having a different, second frequency.

60. The method of claim 59 wherein the first ultrasonic emitter is matched to the first frequency and the second ultrasonic emitter is matched to the second frequency.

61. A method of processing an audio signal including the steps of:

separating the audio signal into a plurality of band-limited signals;

modulating each of the band-limited signals onto ultrasonic carrier waves having either the same or different carrier frequencies thereby to create a plurality of modulated signals; and

transmitting each of the modulated signals from separate ultrasonic emitters.

62. The method of claim 61 wherein each of the separate ultrasonic emitters have resonant frequencies that are matched to the frequencies of the respective ultrasonic carrier waves.

63. The method of claim 62 further comprising the step of:

preprocessing at least one of the band-limited signals prior to the modulating step.

64. The method of claim 63 wherein the preprocessing step comprises the steps of:

generating harmonics of the at least one band-limited signal;

combining the harmonics with the at least one band-limited signal.

65. A method of processing an audio signal including the steps of:

modulating the audio signal onto an ultrasonic carrier wave to provide a

modulated audio signal;

separating the modulated audio signal into a plurality of band-limited signals; and

transmitting each of the plurality of band-limited signals from separate ultrasonic transmitters.

66. The method of claim 65 wherein the ultrasonic transmitters are matched to a corresponding characteristic frequency of the respective band-limited signals.

67. The method of claim 65 wherein the separating step is conducted by passing the audio signal through N filter banks having passbands centered at frequencies f_1 to f_N, and the band-limited signals are transmitted from N ultrasonic transmitters having mechanical resonance frequencies equal to f_1 to f_N respectively.

68. An apparatus for processing an audio signal received from an audio source to generate a bass-enhanced signal, including:

a filter to separate a low frequency component from the audio signal;

a harmonics generator to generate harmonics of the low frequency component; and

an ultrasonic modulator to modulate the low frequency component and the harmonics onto an ultrasonic carrier wave.

69. The apparatus of claim 68 further including:

a loudness analyzer to determine an amplification level for the harmonics based on the loudness of the audio signal.

70. The apparatus of claim 68 or 69 further including:

a weighting module to determine an amplification or attenuation level for a low frequency component of interest to be included in the bass enhanced signal.

71. An apparatus for processing an audio signal including:

a filter bank for separating the audio signal into a plurality of band-limited signals;

a plurality of ultrasonic modulators corresponding to the respective band-limited signals to modulate each of the band-limited signals onto an ultrasonic carrier wave; and

a plurality of ultrasonic emitters for receiving and transmitting the modulated band-limited signals.

72. The apparatus of claim 71 wherein each ultrasonic emitter is matched to a characteristic frequency of the modulated band-limited signal transmitted thereby.

73. The apparatus of claim 72 wherein each ultrasonic emitter has a mechanical resonance frequency that is matched to a characteristic frequency of the modulated band-limited signal transmitted thereby.

74. The apparatus of claim 73 wherein the characteristic frequency is the respective frequency of the carrier wave onto which each of the band-limited signals is modulated.

75. An apparatus for processing an audio signal, including:

an ultrasonic modulator to modulate the audio signal onto an ultrasonic carrier wave thereby to create a modulated audio signal;

a filter bank to separate the modulated audio signal into a plurality of band-limited signals.

76. The apparatus of claim 75 further including:

a plurality of ultrasonic emitters to transmit the plurality of band-limited signals.

77. The apparatus of claim 76 wherein each ultrasonic transmitter is matched to a characteristic frequency of the band-limited signal transmitted thereby.

78. The apparatus of claim 76 wherein the ultrasonic transmitter is selected

to have a mechanical resonance that is approximately matched to the characteristic frequency.

79. The apparatus of claim 78 wherein the characteristic frequency of at least one of the band-limited signals is the central frequency of the frequency band that said at least one band limited signal occupies.

80. Apparatus for steering a directional audio beam substantially as herein described with reference to Figs. 2 to 4 and 6 to 7 of the accompanying drawings.

81. A method for steering a directional audio beam substantially as herein described with reference to Figs. 2 to 4 and 6 to 7 of the accompanying drawings.

82. A method of processing an audio signal substantially as herein described with reference to Figs. 8 to 12 of the accompanying drawings.

83. An apparatus for processing an audio signal substantially as herein described with reference to Figs. 8 to 12 of the accompanying drawings.

84. A method of processing an audio signal substantially as herein described with reference to Figs. 13 to 19 of the accompanying drawings.

85. An apparatus for processing an audio signal substantially as herein described with reference to Figs. 13 to 19 of the accompanying drawings.